Phase Diagrams Ti–B–*X* as a Scientific Base for Development of Titanium–Boride Eutectic Alloys

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A creative development could be realized only as a result of complex systematic investigation, which includes phase equilibrium data and alloy composition-constitution-properties relationships. The present report is a part of such complex investigations and deals with phase equilibria in Ti-rich corners of Ti-B-*X* systems, where *X* is Zr, V, Nb, Al, Si, Ge, or Sn, as well as alloy constitution and properties.

Alloys prepared by arc-melting (cooling rates about 100°C/sec) were studied, in states as-cast and annealed at subsolidus temperatures, by light optical and scanning electron and transmission electron microscopy (LOM, SEM and TEM), electron probe microanalysis (EPMA), and X-ray diffraction (XRD) technique. Phase transformation temperatures were determined by DTA, in parallel melting points were measured by optical pyrometer after Pirani & Alterthum technigue.

The systems in the ranges under investigation are characterised by the extent area of eutectic crystallisation of *bcc* metal and boride (TiB) phases. The alloying initiates a little change in the eutectic compositions, *p*-elements (Al, Si, Ge, and Sn) reduce the boron content in the eutectic by ~1-2 at.% and *d*-metals (Zr, V, and Nb) raise by ~1-2 at.% B (hence slightly increased boride content in the eutectic is characteristic of the alloys based on β-(Ti,V) or β-(Ti,Nb)).

Partitioning of alloying elements between titanium matrix and boride phases is radically different for *p*-elements and *d*-elements: *p*-elements (Al, Si, Ge, and Sn) dissolve fully in matrix; *d*-elements (Zr, V, and Nb) partition comparably between titanium and boride phases.

The alloying of binary $Ti_{92.5}B_{7.5}$ alloy with V and Nb causes significant growth of hardness (by 2-2.5 GPa) in the range of $\alpha + \beta$ matrix (at ~10 to ~20 at.% V or Nb) at the temperatures up to 400°C. In this phase field the "strength break-down" temperature (the incipient temperature of transition to the mechanism of deformation controlled by diffusion) decreases by about 100°C (from 500 to 400°C).

The titanium-boride alloys based on the stabilized β-phase with the minimal V or Nb content (24 to 30 at.%) have the low hot hardness and "strength break-down" temperature (close to the initial $Ti_{92.5}B_{7.5}$). The further alloying with the same metal (V or Nb) has essential effect on both hardness (raised by 2-2.5 GPa up to 400°C and by 1 GPa at 700°C) and "strength break-down" temperature (elevated to 600°C), which offer some perspectives. High-alloyed eutectic alloys based on β-matrix showed the high level of hardness, especially at the temperatures 500 to 700°C.

In the Ti-Si-B and Ti-Ge-B systems the study revealed a fine eutectic structure that is formed by titanium phase and silicido-boride or germanido-boride (T) of unknown structure type. The (Ti) + T + TiB eutectic structure is characterized by high dispersivity, thickness of reinforcing rods and matrix are 0.2-0.3 μ. It possesses high hardness from room temperature to 500°C and to be of interest for development of new materials. In the alloys the unknown ternary phase was also found that forms the similar fine eutectic.

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